Increasing Broadcast Reliability in Vehicular Ad Hoc Networks

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Problems with Broadcasts

- Broadcast transmissions are the predominate form of network traffic in a VANET.
- No retransmission is possible for failed broadcast transmissions because of the lack of explicit acknowledgement (ACK) for broadcast frames.
  - There is no way to determine if a broadcast frame is received or not.
- The hidden terminal problem exists because the RTS/CTS exchange is not used.
  - Because the RTS/CTS is not used channel reservation is not possible.
- The contention window size fails to change because there is no MAC-level recovery on broadcast frames.
  - Nodes will always transmit with CW_{min} for the backoff window.

Modified Broadcast Protocol

- We rely on the observation that a node in a VANET is able to detect collisions and congestion by simply analyzing the sequence numbers of packets it has recently received.
- While a node does not know if the packets it sent are correctly delivered, it knows the exact percentage of packets sent to it from its neighbors that are successfully received.
- Based on this receiver feedback, a node is able to dynamically adjust its transmission parameters to improve the delivery rate of broadcast messages.
- The probability of collisions can be reduced and probability of reception can be improved if the size of the CW used to send broadcast messages is able to adapt based on the network conditions.

Collision and Congestion Detection

frames received from Node B	32		34	35	36	37	38		40	41
frames received from Node C	7	8	9				13	14	15	16
frames received from Node D	15	16		18	19		21	22	23	24
frames received from Node E	62	63	64	65		67	68	69	70	71

- A 12 bit sequence number is contained in the sequence control field of a MAC header.
- Node A records that it has overheard the frames coming from node B with the sequence numbers: 32, 34, 35, 36, 37, 38, 40 , and 41.
- Based on the observation, node A can conclude that the frames sent from node B with the sequence numbers 33 and 39 were corrupted or lost.
- Each node then records the overheard sequence numbers coming from specific nodes.

Data Maintained by Each Node

MAC Address	Sequence Number	Average Reception Rate	Timestamp

- A dynamic hash table is used so that a table entry is updated in near constant time. The MAC address is used as the key to the hash function.
- Each table entry has a timestamp associated with it. In order to prevent old data from affecting the calculation of the local network conditions. Old entries are removed from the table when the local reception rate is calculated.
- The average reception rate is a weighted average and is used to determine the percentage of packets that are successfully received from a specific node.

Reception Rate

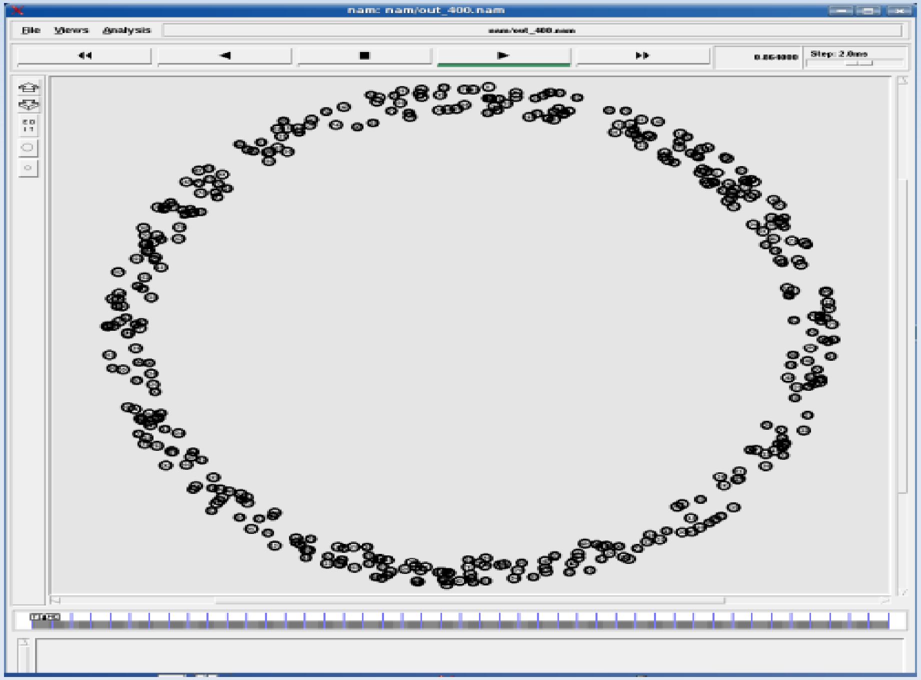
- Each time a frame is successfully received, the weighted reception rate is recalculated.
- The variable α is used to put more or less weight on the current network condition.
  - $\text{EstRecpRate} = \alpha * \text{EstRecpRate} + (1 - \alpha) * \text{SampRecpRate}$
- The nodes also maintains a timer. When the timer expires, the local reception rate is determined and the CW is adjusted.
- The local reception rate is the average of the estimated reception rates.
  - LocalReceptionRate = ∑ EstRecpRate / Nodes

Contention Window Adjustment

- After the local reception rate is calculated, it is compared against the previously stored local reception.
- The node also maintains a threshold value that it uses to determine whether to increase or decrease the CW.
- If the new local reception rate decreases by a value greater than the threshold, the CW is increased.
- On the other hand, if new local reception rate increases by a value greater than the threshold, the CW is decreased.
- As a result, the CW adapts to the condition of the network.
- The node then uses the new CW for all broadcast transmissions until the next time the local reception rate is calculated.

Metrics and Topology

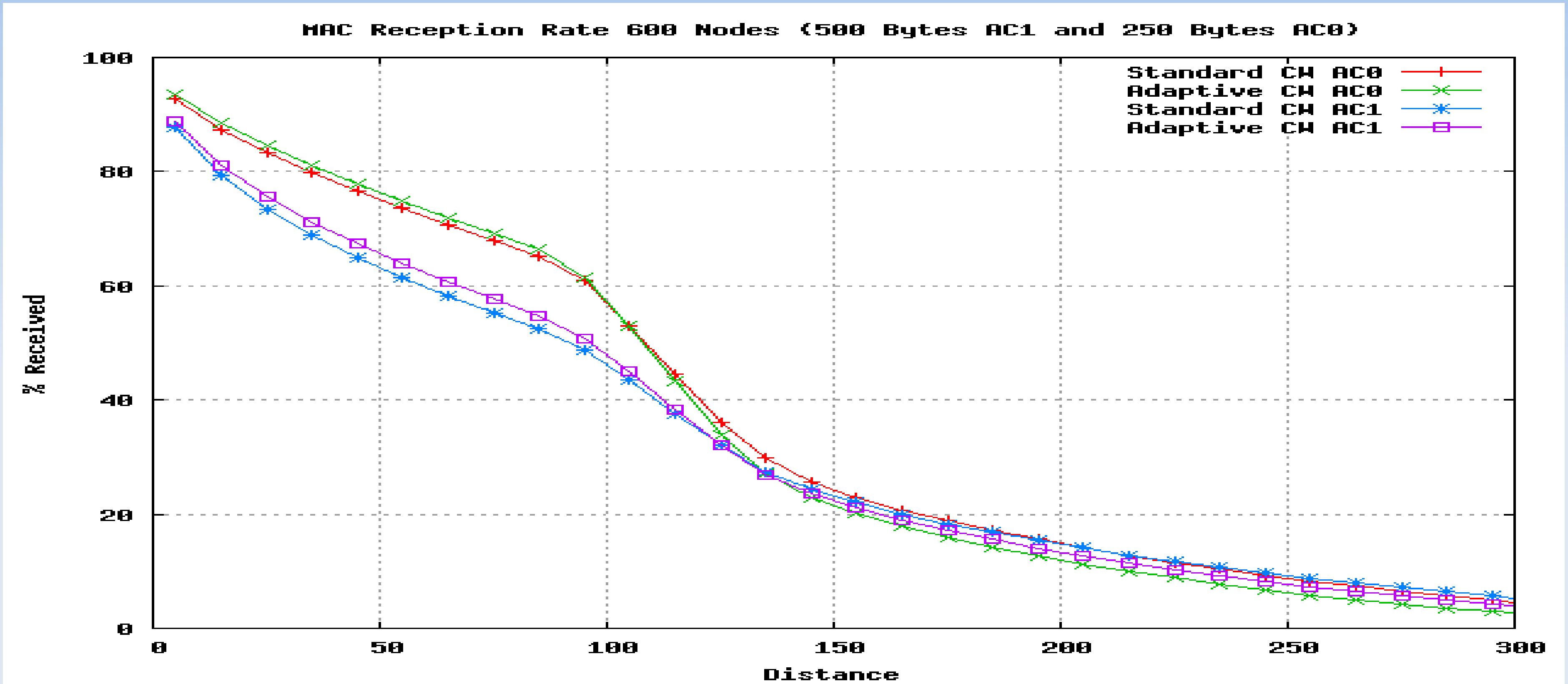
- Channel access time: the elapsed from when a packets is passed to the MAC layer until it is put on the channel.
- Reception rate: the percentage of packets successfully received at a distance d± 5m from the sender.

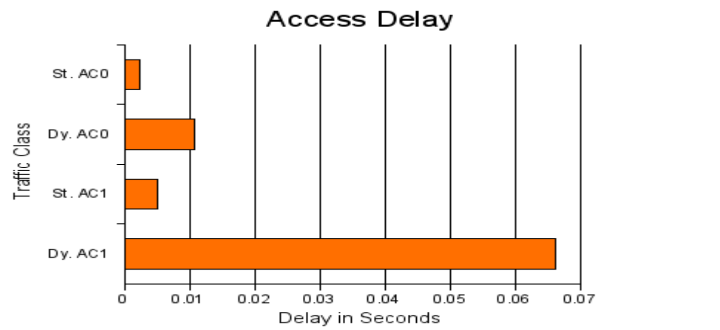


Adaptive CW Simulation

- The mobility model used in the simulations is Freeway Mobility Model. Each node in the simulation is restricted to only travel within its lane. Also, the velocity of each node is temporally restricted based on the nodes previous velocity.
- AC[0] accounts for 20% of the traffic and AC[1] accounts for 80% of the traffic.
- AC[0] is used to transmit emergency warnings. Nodes are randomly selected to transmit 500 byte emergency warning and they are transmitted once every 100 ms for 1.5 s with 10% jitter.
- AC[1] is used to transmit 250 byte packets containing a vehicle's state every 0.1 seconds with 10% jitter with .
- AC[0] CW_{min} = 7, AC[0] CW_{max} = 31, and AIFS[0] = 2
- AC[1] CW_{min} = 15, AC[1] CW_{max} = 511, and AIFS[1] = 3

Simulation Results for the Dynamic CW

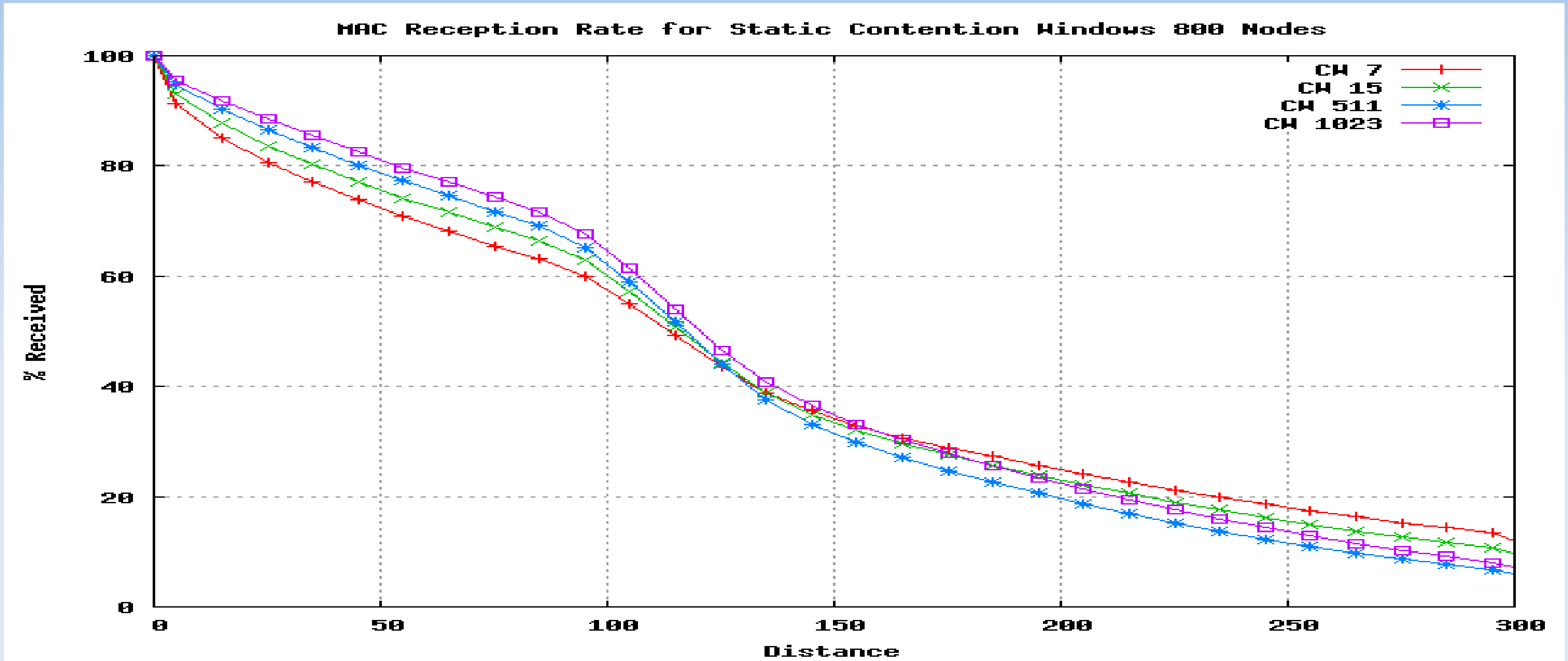


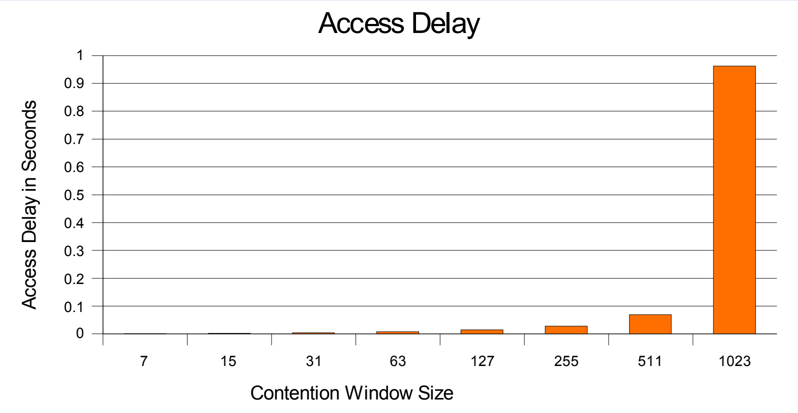


The Effect Different Static CW Sizes Have on Reception

- Another set of simulations was used to determine the effect that different values of CW_{min} have on the reception rate.
- The results show that it is unlikely to be able to increase the reception rate by more than about 5%.
- One interesting finding was the a larger CW results in a lower probability of reception at large distance, while the reception is improved at short distances.
- For light network traffic the reception rate does not improved much as a result of varying the CW.
- For heavy traffic the rate improves but the queues can also fill up causing packets to be dropped and causing excessive delays.

Fixed Contention Window





Conclusion

- Dynamically adjusting the CW has a limited impact on the reception rate.
- The static analysis shows that at certain distances a 5% to 6% increase in the reception rate is achieved by increasing the CW from $CW_{min} = 7$ to $CW_{min} = 511$.
- One interesting finding was that larger CWs resulted in a lower probability of reception at large distance.
- The dynamic CW results in slightly lower increases in the reception rates.
- Dynamically adjusting the contention window improves the rate of reception under certain conditions.
- If the amount of network traffic is close to the theoretical limit, it would be beneficial instead to drop some packets or to adjust the packet transmission rate. In this case increasing the CW has a limited impact.

Future Work

- Adaptive Transmission Rate
  - Due to the hidden terminal problem it is unrealistic to expect to achieve anywhere near 100% delivery of broadcast frames.
  - In the case of a highly load network nodes will have to decrease their transmission rate.
  - The feedback from the network can be used to reduce the transmission rate of low priority traffic.
- Dynamic Power Control
  - Controlling the communication range by adjusting the transmission power can be used to mitigate the adverse effects of highly dense nodes.
  - The transmission range can also be adjusted to keep the network load on the medium below a certain threshold.